the lateral gill-slits are still visible, are even larger as compared with the parent animal than is the case in *Cæcilia compressicauda*. According to this, one might almost believe that such a relation in size is universal in the embryo Cæcilians. On the other hand, one might conjecture that a development with external vesicular gills, which obtains only exceptionally amongst the *Anura*, as in *Opisthodelphys* and *Nototrema*, occurred more commonly amongst the Cæcilians. The few observations however which have as yet been made on the other species of Cæcilians do not confirm this. Thus A. Dumeril, in a young *C. oxyura*, 50 millims. long, has found on each side of the neck a branchial cleft, which it is true lies somewhat higher than in *E. glutinosum*, but still proves that in this species no external vesicular gills are developed (*Mem.* Soc. Sc. Nat. Cherbourg, ix., taf., 1 Fig. 8).

Further, Prof. Möbius on the occasion of his late visit to the Seychelles, brought back several examples of *C. rostrata* (Cuv.), of very varying sizes (from 35 to 240 millims.) which have neither branchial clefts, nor a swimming-tail, nor do they show the scars on the neck that accompany the vesicular gills. All this leads one to conclude that the development of the Cæcilians, like that of the *Anura*, goes on in very various ways, and that in this field too important discoveries are still to be made. It cannot therefore be too deeply impressed on naturalists who visit tropical countries where Cæcilians are found, to give to this subject their especial attention."

PHILOSOPHY OF THE PUPATION OF SOME BUTTERFLIES[1]

THE comparatively sudden transitions from one state to another in insects, have always excited the keenest interest. The change from larva to chrysalis in those butterflies known as *suspensi*, and which in the chrysalis state hang from the tip of the body, has, perhaps, been looked upon as the most wonderful. The preliminary acts in the performance have been pretty well observed and described by various authors since the days of Vallisnieri. The larva hangs by the anal end, turning up the anterior part of the body in a more or less complete curve, and the skin finally splits from the head to the front edge of the metathoracic joint, and is worked back in a shrivelled mass towards the point of attachment. Now comes the critical feat which has most puzzled naturalists, viz., the independent attachment of the chrysalis and the withdrawal from, and the getting rid of, the larval skin which such attachment implies.

Réaumur explained it in 1734 by the clutching of the larval skin between alternate sutures of the soft joints of the chrysalis; and his happy and circumspect account from observations made on *Vanessa urticæ* has formed the basis for subsequent accounts; no one obtained a deeper insight into the philosophy of the act until, some two years since, Dr. J. A. Osborne, of Milford, England, discovered that a distinct membrane is concerned in it. In casual observations of the process I had long become convinced that the popular accounts were crude and inaccurate, and I had preserved specimens in the act of transforming, for future study; but the philosophy of the change cannot be satisfactorily made out from alcoholic specimens alone, nor from the study of one species. The present paper is based on observations made on species belonging to more than a dozen genera, the conclusions having been partially presented last June to the Philosophical Society of Washington.

The body of the larva is composed (exclusive of the head) of twelve segments or joints, *and a sub-joint*. It is with this subjoint that we have here to deal, for to it beneath the rectum are appended the anal pro-legs, and above this is the anal plate.

If we carefully examine the anal plates of the larvæ of the true *suspensi*, we shall find that while they differ in form they have one feature in common, viz., the being furnished dorsally and posteriorly with numerous short spines and points generally retrorse, or so placed that the larva can make use of them in suspending. These special spines on the anal plate are only fully developed after the last larval moult, being more or less obsolete in the earlier stages, and they are also under muscular control. Even in the *succincti*, where, as a rule, the anal plate is not specialised, spines are, nevertheless, sparsely found, especially on the border.

All writers whom I have consulted speak of the larval suspension being due to the entanglement of the hooks of the anal pro-legs in the silk, and do not mention the use of the anal plate, for which the hillock of silk is sometimes spun in special form.[1]

The normal form may be likened to that of an inverted settee, or shoe, or to a ships-knee, and one of the most interesting acts of the larva, preliminary to suspension, is the bending and working of the anal parts in order to fasten the back of the plate to the inside of the back of the settee, while the crotchets of the legs are entangled in the more flattened position or seat. In some cases (as in *Danais*) the hillock of silk is more elongate, and the spines of the truncate plate mostly occur around the lower margin and even beneath it, so that in fastening them the larva seems to be drawing the silk up the rectum. In other cases (as in *Euptoieta*) the plate, in addition to the spines, has a prominent tubercle on each anterior outer border well calculated to lock securely into the silk. After suspension, and as the fluids gravitate anteriorly, the silken hillock becomes more conical (the threads being loosely spun and elastic) and the hooks both of the plate and the pro-legs hang more loosely from it.

In the final getting rid of the larval skin and attachment of the chrysalis there are concerned—

1. Certain factors belonging to the larva and cast off with its skin. 2. Those belonging to the chrysalis; and to intelligibly explain the process it is necessary to more fully characterise and homologise these parts than has hitherto been done.

In the former category, in addition to the natural adhesiveness of the moist, mucous, and membranous corium,[2] there are three physiological factors concerned: (1) the *tracheal ligament*, or the shed tracheæ from the last or ninth pair of spiracles which uniformly become blind or obsolete in the chrysalis; (2) the *rectal ligament* or shed intestinal canal; (3) the Osborne or retaining membrane (*membrana retinens*), which is but a stretched part of the membranous corium that accumulates around the rectum and in the anal pro-legs.

In the second category we have the structural features of the chrysalis. These are, first, the *cremaster* proper, which is the homologue of the anal plate of the larva, and the form of which is foreshadowed in that of said anal plate. This cremaster assumes a great variety of different forms, but in general may be said to be a tapering piece more or less incurved ventrally, and having the ventral and dorsal margins thickened or ridged, and these ridges may be respectively called the *ventral* and the *dorsal cremastral ridges*. This cremaster is surmounted at the apex and sometimes along the ventral ridges by what may be called the *cremastral hook-pad*, thickly studded with minute but stout hooks, which are sometimes compound or furnished with barbs very much as are some of our fishing-hooks, and which are most admirably adapted to the purpose for which they are intended.

Secondly, we have the sustainers (*sustentores*), two projections which homologise with the soles (*plantæ*) of the anal pro-legs, and which take on various forms, but are always directed forward, so as to easily catch hold of the retaining membrane. In the yellow butterflies (as *Callydrias*, *Terias*, *Colias*), where the body of the chrysalis is so thrown back that mere projecting tubercles would not suffice, we find them transformed into actual hooks; while in some of the *succincti* they are little more than a thickening of the anterior margin of the sub-joint. In all lepidopterous pupæ these remnants of the anal pro-legs are more or less indicated, while in certain moths (*Pterophoridæ*) where the pupa is partly suspended, they are, as in the *Nymphalidæ*, covered with long hooks similar to those at the tip of the cremaster.

Thirdly, we have what may be called the *sustentor ridges*, usually connected with the sustainers, embracing them on the outside, and extending backward to the inside of the ventral cremastral ridges, and sometimes, as in *Paphia* and *Limenitis*, forming quite a deep notch, which doubtless assists in catching hold of the larval skin in the efforts to attach the cremaster.

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[1] Abstract of a paper read before the American Association for the Advancement of Science, by Prof. C. V. Riley.

[1] It is an interesting fact in this connection that Roesel, who has never had any superior as a delineator of insect larvæ, makes the Nymphalids in his figures all suspend to an elongate conical piece of silk apparently issuing from the anus, with the legs invariably free and in no instance hooked. It is evident, however, from his text, that he was not aware of the use of the anal plate, and since he speaks of the larvæ attaching themselves by the hind legs or extremities, it is equally evident that his figures do not correspond with the text, while the freedom of the legs in his figures is, of course, an error

[2] What is here termed the *corium* is the membranous layer between the separating larva skin and the forming chrysalis. If, as recent investigations seem to show, it is only the outer half of the dermal layer of the skin which is cast off in the exuviation of invertebrates, and not the whole skin with its three layers, then this membrane is developed between the splitting parts of said outer layer, and is not, strictly speaking, the *corium*.

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These sustentor ridges are homologous with the limb of the anal pro-legs and the exposed edge with the posterior border of said limb. They vary much in form, and may be more or less obsolete.

Fourthly, between them is what may be called the *rectal piece*, consisting of a piece more or less well marked and elevated, especially around the closed rectum.

It is principally by the leverage obtained by the hooking of the sustainers in the retaining membrane, which acts as a swinging fulcrum, that the chrysalis is prevented from falling after the cremaster is withdrawn from the larval skin. It is also principally by this same means that it is enabled to reach the silk with the cremastral hook-pad. Yet the rectal ligament plays a most important part, and in some species a more important part even, in my estimation, than the membrane itself. The tracheal ligaments which, from a study of specimens plunged in alcohol when the larval skin was about half shed, I was at first inclined to believe important auxiliaries, are, I am now satisfied, of very little if any service in most cases. The rectal ligament is a constant physiological factor, and its importance cannot be ascertained by attempts to sever the membrane at the critical moment, because in such attempts the ligament is more or less drawn out beyond the power of the sphincter muscles in the chrysalis to control it.

Dissected immediately after suspension, the sub-joint of the larva will be found to be lying, especially between the legs and around the rectum, in an abundance of translucent, membranous material. An hour or more after suspension the end of the forming chrysalis begins to separate from the larval skin, except at the tip of the cremaster. Gradually the skin of the legs and of the whole sub-joint stretches, and with the stretching the cremaster elongates, the rectal piece recedes more and more from the larval rectum, and the sustentor ridges diverge more and more from the cremaster, carrying with them, on the sustainers, a part of the soft membrane. If a larva be carefully dissected at this stage, the forming membrane may be raised with the point of a needle, and stretched so as to show its connection with the rectal ligament; or it may be lifted entirely from the retainers, when, by its elasticity, it contracts, and becomes more or less fully absorbed in the rectal ligament. It is at this stage that the strength of the latter may be fully tested, and if the chrysalis, flayed from the larval skin, and freed from the retaining membrane, be grasped in the neighbourhood of the rectum, so as to supply the natural holding power of the sphincter muscles, the rectal ligament will sustain, as I have abundantly proved, at least ten or twelve times the weight of the chrysalis; while it will support, if held by the larval skin, several times the weight of the chrysalis before separating therefrom. In brief, the retaining membrane is that part of the inner larval skin surrounding the pro-legs drawn down by the sustainers, and always intimately connected with and forming but a branch of the rectal ligament. When extended from its attachments, as when the chrysalis rises to the silk, this membrane dries, and in the cast-off larval skin retains more or less perfectly the stretched form. If the corium of the larva be thick and strong, as in *Vanessa*, the dried membrane will be broad, with two indentations where it was held by the retainers; if the corium be more delicate, as in *Danais*, *Paphia*, or *Apatura*, the dried membrane will be more forked, showing how the retainers have acted upon its elasticity. In every case, however, it shows, under the microscope, the longitudinal folds and creases incident to the stretching, and, compared to the rectal ligament proper, it seems to lose importance as it is less needed; for the *succincti* will generally attach when it is severed or loosened from the retainers, while in *Apatura* (at least as exemplified in the North American species), which combines the peculiarities of both the *succincti* and *suspensi*,[1] it does not become specialised, and the chrysalis seems to rely almost entirely on the rectal ligament, assisted by the partial holding of the delicate larval skin, not only between what is left of the sustainers and the ventral posterior margin of the twelfth joint, but between the ventral sutures of this last and the preceding joint. And here I would remark, in conclusion, that the ventral borders of two or three of the joints preceding the subjoint are, in most chrysalids which I have studied, so hardened that the larval corium is actually grasped between them and the deep sutures made in contracting. In some instances (especially in some species of *Papilio*) the posterior border of the twelfth joint is produced into a medial transverse ridge fully as prominent as that formed by the sustainers, which here are flattened and coalesce; so that the sutures of some of the terminal joints in the chrysalis do subserve the purpose ascribed to them by Réaumur, but in a somewhat different way.

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[1] The larva of *Apatura* attaches horizontally, making the front pair of abdominal pro-legs answer the purpose of the girth; but in the shedding of the skin this attachment is severed, and the forming chrysalis assumes the perpendicular position, and in the withdrawal and attachment of the cremaster it acts as the true *suspensi*.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE

THE Oxford *University Gazette* of October 10 contains counsel's opinions on the proposed faculty of Natural Science at Oxford. It has been proposed that the University should, by statute, establish a new faculty, under the name of "The Faculty of Natural Science," should grant degrees of Bachelor and Master in that faculty, and should give to Masters of Natural Science all the rights and privileges which are now enjoyed by Masters of Arts, so making them Members of Convocation (the governing body of the University), and enabling them to vote for the members returned to Parliament by the University. Mr. Horace Davey is of opinion that the University may create a new faculty in science, or (which comes to the same thing) may sever one of the sciences or philosophies formerly comprised in the Faculty of Arts, and may make it into a new faculty, and grant degrees therein. Such a severance was anciently made in the case of grammar, rhetoric, and music. But Mr. Davey believes that the University has no power to confer upon graduates in a new natural science faculty the rights which now belong to Masters of Arts, and the degree of Bachelor or Master of Natural Science would not make the holder a Member of Convocation. This difficulty Mr. Davey suggests, might be avoided by the University conferring the degree of Master of Arts on any person obtaining the corresponding degree in the new faculty.

The new chemical laboratories at the Oxford University Museum will be opened for students this term. The chemical department has now for many terms been overcrowded, and the new buildings will not only afford ample space for beginners and pass-men getting up their "simple salts," but contain rooms set apart for special work and fitted with the best appliances under the careful superintendence of Mr. W. W. Fisher, Aldrichean Demonstrator.

The new chemical laboratory at Balliol College will be opened this term under the superintendence of Mr. H. B. Dixon. Balliol and Trinity Colleges have combined to equip and maintain this laboratory, and a physical lecture room for the use of their own students.

At the University Museum Prof. Odling will lecture, this term, on Organic Chemistry; Mr. Fisher will lecture on Elementary Organic, and Mr. Donkin on Elementary Inorganic, Chemistry. Prof. Clifton will lecture on Elementary Electricity, and Prof. Story-Maskelyne on the Use of the Goniometer. Prof. Prestwich gives a course on two afternoons a week, on the Palæozoic Rocks, at the Museum, and Prof. Lawson will lecture on Vegetable Histology, at the Botanic Garden. Rev. C. Pritchard, Savilian Professor of Astronomy, will give practical instruction at the University Observatory, on fine evenings during the term; he will also continue giving public lectures on the history of astronomy. Dr. Rolleston will lecture on Circulation and Respiration, and practical instruction in anatomy and physiology will be carried on in the laboratory, under the superintendence of Mr. Robertson, Mr. Jackson, and Mr. Poulton. Mr. Barclay Thompson will lecture on the Anatomy of the Amphibia, at the Museum. At Christchurch Mr. Vernon Harcourt will give a course of lectures on the Elements of Chemistry, and Mr. R. E. Baynes will give a course on Mechanics.

At Magdalen College Laboratory Dr. Pike will lecture on Chemistry, and Mr. Yule and Mr. Chapman on Biology.

Exeter College has lost the valuable services of Prof. Lankester. Mr. Lewis Morgan, formerly house surgeon at the Radcliffe Infirmary, will carry on instruction in the biological laboratory of the College.

In the month of November there will be an election at Balliol College to a scholarship on the foundation of Miss Hannah Brakenbury, "For the Encouragement of the Study of Natural Science," worth 80*l.* a year (55*l.* and tuition free), tenable during residence for four years. There is no limit of age, but members of the University must not have exceeded eight terms from

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